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Air Pollution Assessment of Carbon Tetrachloride

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Air Pollution Assessment of Carbon Tetrachloride

RICHARD JOHNS

FEBRUARY 1976

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This report concerns the organochlorine solvent carbon tetrochloride, which is used primarily in the manufacture of fluorocarbons. The toxic effects of the solvent in both animals and man are discussed and the probability of those effects occurring at the ambient atmospheric concentrations to which the general population is exposed is assessed. Methods for atmospheric sampling of carbon tetrachloride and available control technology for the prevention of release to the environment are also discussed.

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I. SUMMARY AND CONCLUSIONS

Carbon tetrachloride is a colorless, nonflammable liquid, possessing excellent solvent properties for fats, oils, plastics and many organic chemicals. It is not highly reactive and is neither oxidized readily in air nor hydrolyzed rapidly in water. The chemical is decomposed to toxic products such as hydrogen chloride and phosgene on contact with hot metal. It is estimated to have a half-life of 10 to 33 weeks toward atmospheric photodegradation. An octanol/water distribution coefficient of 2.64 indicates a mild tendency for carbon tetrachloride accumulation in body lipids.

Depending upon the organism and route of administration, certain concentrations of carbon tetrachloride result in toxic, carcinogenic, or mutagenic activity in mammals, the liver being the primary center of damage. Hepatotoxicity of the compound is enhanced by certain dietary factors, particularly alcohol ingestion. The chemical is absorbed through the lungs and from the gastrointestinal tract, but only marginally through the skin. Carcinogenic studies using laboratory animals have shown tumors of the liver to result from repeated oral and subcutaneous administration of the chemical. The appearance of hepatomas in man, several years after carbon tetrachloride poisoning, has been reported in several cases. Several biochemical indices have been developed recently which forewarn of clinical symptoms of chronic exposure to carbon tetrachloride. The American Conference of Govern-

mental Industrial Hygienists has recommended a threshold limit value of 65 mg/m^3 (10 ppm), which has been adopted by the Occupational Safety and Health Administration (OSHA) as a maximum 8-hour-average level for workplace atmospheres. The odor threshold of carbon tetrachloride is about 500 mg/m^3 and, hence, is entirely inadequate as a signal of danger.

Ambient data on localized carbon tetrachloride concentrations are sparse; hence, population exposure is not widely assessable from experimental data. A study in the Los Angeles Basin revealed an atmospheric concentration range of 1 to 2 $\mu g/m^3$ over 54 ground-level stations, with an excursion to 10 $\mu g/m^3$ at one site. Analytical measurements were made using a gas chromatograph equipped with an electron capture detector. This is the method of choice for halohydrocarbons, and is capable of detecting carbon tetrachloride at the parts-per-billion level.

Exposure over a 75-year lifetime to the 2 $\mu g/m^3$ level of carbon tetrachloride found in the Los Angeles Basin is approximately equivalent to one day's occupational exposure at the OSHA limit of 65 mg/m^3. The atmospheric concentration of the chemical near production facilities may be estimated with an atmospheric diffusion model. For a typical carbon tetrachloride plant, an atmospheric concentration of 1.4 mg/m^3 at a point 500 meters downwind of the plant is developed. Exposure to this concentration over a 75-year lifetime is equivalent in dose to

a 7-year occupational exposure at the OSHA limit for workroom atmospheres. The downwind distance of 500 meters is representative of a location near the property line of a production facility.

Population exposure may arise from dispersive uses of carbon tetrachloride, but levels of exposure are unknown. The use of the product as a fumigant for rodents carries the potential for exposure of building occupants, neighbors, and bystanders. Solvent use has declined and carbon tetrachloride is no longer generally available as a consumer product. The high vapor density of this compound warrants concern for localized ground-level vapor sinks which may accumulate hazardous levels of carbon tetrachloride. Such sinks can be envisioned, for example, in basements of buildings undergoing fumigation.

The chemical can enter the environment through various routes. Losses to the atmosphere are possible in the production, handling, and distribution of carbon tetrachloride. Dispersive uses of the chemical contribute further to the atmospheric burden, although they account for only a small fraction of consumption. Carbon tetrachloride is ubiquitous in the troposphere, and global studies indicate a natural occurrence of the compound. At an altitude of 5 to 10 km, the background is typically 0.5 to 1.0 $\mu g/m^3$ carbon tetrachloride. From global atmospheric measurements, it can be estimated that the worldwide atmospheric burden exceeds the total production of carbon tetrachloride during this century by at least twentyfold, thus indicating the likelihood of a non-industrial source. The compound has been found in a variety of

environmental samples at the parts-per-billion level, but no significant accumulation in the food chain has been shown.

Carbon tetrachloride is produced at 11 plant sites in the United States, largely concentrated in the Gulf Coast area. The compound ranks as a major industrial chemical, with annual production in excess of one billion pounds. The bulk of carbon tetrachloride production (95 percent in 1973) is used in the manufacture of fluorocarbons (trichlorofluoromethane and dichlorodifluoromethane); hence, the market is highly sensitive to the demand for aerosol products. Demand grew at a rate of 6.8 percent per year from 1960 to 1970, but has shown a leveling trend due to slowing growth of aerosol products. Should the use of fluorocarbon propellant be banned in the future, demand for carbon tetrachloride could be expected to diminish to about 45 percent of its current level.

Two critical considerations in the air pollution assessment of carbon tetrachloride are: (1) accumulation of man-made residues of the chemical in the upper atmosphere, and (2) exposure risk in the vicinity of sources of the chemical. The latter consideration relates directly to the health of population groups near sources, whereas the former concerns the steady-state composition of the troposphere and attendant health effects. Occupational and consumer exposure to carbon tetrachloride vapor are not air pollution problems in a strategic sense.

The evidence for natural sources of carbon tetrachloride implies

that the relative atmospheric contribution from anthropogenic sources is minor. Based on available evidence, there appears no need for additional control of carbon tetrachloride emissions so far as the total atmospheric sink is concerned.

Measured concentrations of carbon tetrachloride in urban atmospheres, as well as estimated levels near production facilities, are not significantly greater than the worldwide background of 0.5 to 1.0 $\mu g/m^3$. These levels are about five orders of magnitude below the threshold limit value and, hence, pose no probable risk to local populations near sources.

The risk from dispersive applications of carbon tetrachloride is difficult to control. The threshold limit value is exceeded by the evaporation of one milliliter of the solvent into a 3-meter cubical room.

Carbon tetrachloride and other chlorohydrocarbons are scheduled for study by the National Institute for Occupational Safety and Health during 1976. Occupational risk will be the primary focus of this work, but "fenceline" measurements may be included in the study. A study of the carcinogenic potential of carbon tetrachloride is in progress at the National Cancer Institute.

II. AIR POLLUTION ASSESSMENT REPORT

A. PHYSICAL AND CHEMICAL PROPERTIES

Carbon tetrachloride is a colorless, nonflammable liquid, possessing excellent solvent properties for fats, oil, plastics, rubber, and many organic chemicals. The principal physical properties of the compound are shown in Table I. The chemical shows no oxygen uptake in the standard BOD test*, nor is it readily decomposed by photodegradation. Carbon tetrachloride is estimated to have a half-life of 10 to 33 weeks toward atmospheric photodegradation (1). The vapor is decomposed above 200°C into hydrogen chloride, chlorine, phosgene and other products. The production of toxic degradation is enhanced by the presence of hot metal; hence, the former use of the chemical in small fire extinguishers has been abandoned. At 250°C, carbon tetrachloride becomes an active chlorinating agent for oxides of metals such as aluminum and zinc.

Carbon tetrachloride hydrolyzes very slowly in contact with water, showing a half-life of 70,000 years at a pH of 1.0 to 7.0. Hydrolysis is accelerated by the presence of iron, zinc, and other metals. The chemical is inert to strong acids, but is decomposed by strong alcholic alkali or strong bases to simple inorganic products. An octanol/water partition coefficient** of 2.64 (Table I) indicates a mild tendency

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*Biochemical Oxygen Demand. A measurement of oxygen consumption during controlled biochemical degradation.

**A partition coefficient expresses the equilibrium concentration ratio of a solute between two phases which are in mutual contact.

TABLE I

CARBON TETRACHLORIDE

Physical Properties

Chemical Formula	CCl_4
Molecular Weight	153.84
Boiling Point	76.9°C
Melting Point	-22.9°C
Vapor Pressure, 25°C	115.2mm Hg
Specific gravity, liquid	1.589
Specific gravity, vapor vs. air	5.32
Refractive Index, 20°C	1.4607
Solubility, Water	0.8 g/l
Solubility, Octanol	∞
Partition Coefficient, Octanol/Water	2.64
Partition Coefficient, Water/Air, V/V, 20°C	1.1

Sources: Kirk, R. E. Encyclopedia of Chemical Technology, Second Edition. New York, Wiley, 1968.

National Science Foundation Panel on Manufactured Organic Chemicals, SRI Data, 1975.

for carbon tetrachloride accumulation in body lipids. Carbon tetrachloride shows a water/air partition coefficient of 1.1, expressed in terms of volume. This indicates that the chemical is slightly more soluble in air than in an equal volume of water. In terms of mass, this indicates that the chemical is about 1,000 times more soluble in air than in water. Reduced to practical considerations, a body of water swept with air will tend to transfer its carbon tetrachloride content to the air phase, which will be the primary medium of environmental transport.

B. EFFECTS

Carbon tetrachloride has been shown to be toxic to mammals by a variety of exposure routes. It is readily absorbed in the mammalian gastrointestinal tract or lung, while little dermal absorption occurs. The absorption rate of ingested carbon tetrachloride is greatly affected by the diet; ethanol consumption or high-fat diets will greatly enhance carbon tetrachloride uptake (2). Any absorbed carbon tetrachloride will be metabolized, though rather slowly, in the liver. This slow rate of degradation is thought to be a primary factor in the toxicity of carbon tetrachloride (3). The liver and kidney are usually the first organs to evidence dysfunction or destruction as a result of carbon tetrachloride exposure by ingestion or inhalation (2). Because of the rather slow degradation rate, repeated exposure to carbon tetrachloride, even at low doses, becomes significant. The relative acute toxicity of carbon tetrachloride to selected mammalian species is shown in Table II, emphasizing variability in terms of species, routes of administration, and exposure period.

The American Conference of Governmental Industrial Hygenists (ACGIH) has recommended a threshold limit value (TLV)* for carbon tetrachloride in the workplace of 65 mg/m^3 (10 ppm). The odor threshold of carbon tetrachloride is approximately 500 mg/m^3 and, hence,

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*The minimum concentration known to produce a physiological response.

TABLE II

ACUTE TOXICITY OF CARBON TETRACHLORIDE

ANIMAL	ROUTE	DOSE	DOSAGE	LENGTH OF EXPOSURE	REFERENCE
Rat	Inhal.	LC_{50}	2515 mg/m^3	7 hr/day; 5 day/wk	Adams et al, Arch. Ind. Hyg. Occ. Med. 6; 50 (1952)
	Inhal.	MLC	150 g/m^3	30 min.	Spiegel et al, AEC Report #MDDC-1715 '947/48)
	Inhal.	LC_{50}	50 g/m^3	4 hr.	Tox. Appl. Pharm. 18; 168 (1971)
	Oral	LD_{50}	7460 mg/kg		Smyth, unpb. data, Mellon Institute
	Oral	LD_{50}	2920 mg/kg		McCollister, et al, Arch. Ind. Hyg. 13; 1 (1956)
Mouse	Inhal.	MLC	51 g/m^3	104 min.	Muller, Arch. Exp. Path. Pharm. 109; 276 (1925)
	Oral	MLD	6000 mg/kg		J. Nat. Can. Inst. 30; 837 (1963)
	Oral	LD_{50}	12800 mg/kg		Dybing, Acta pharm 2; 233 (1946)
	SC	LD_{100}	3554 mg/kg		Rothschild, Hospital 27; 1017 (1945)
Hamster	Oral	MLD	320 mg/kg		Fuhner, Arch. Exp. Path. Pharm. 97; 86 (1923)
Rabbit	Oral	LD	6380-9975 mg/kg		Lamson, J. Pharm. Exp. Ther. 22; 215 (1923)
	Oral	LD	900-10,700 mg/kg		Fuhner, op. cit.
Cat	Inhal.	MLC	90 g/m^3	70 min.	Reuss, Thesis, Worzburg (1932)
	SC	LD_{33}	4785 mg/kg		Cantarow, et al, J. Pharm. Exp. Ther. 63; 153 (1938)
Dog	Oral	MLD	4000 mg/kg		Barsoom et al, Qtly. J. Pharm. 7; 205 (1935)
	Oral	LD	25000 mg/kg		Lamson, op. cit.
	IV	MLD	125 mg/kg		Barsoom, op. cit.
Human	Inhal.	MLC	125 mg/m^3		Elkins, Chem. of Ind. Tox. 2nd Ed., Wiley N.Y.
	Inhal.	MLC	6288 mg/m^3		Amer. Pest Cent., Inc., Kansas, (1966)

Inhal. - Inhalation
SC - subcutaneous
IV - intravenous
LC - lethal concentration
LD - lethal dose
MLD - minimum lethal dose
MLC - minimum lethal concentration
LC_{50} - concentration lethal to 50 percent of a sample population under stated experimental conditions.
LD_{50} - dose fatal to 50 percent of a sample population under stated experimental conditions.
LD_{100} - dose fatal to 100 percent of a sample population under stated experimental conditions.

would certainly not be considered a satisfactory warning of excessive exposure.

Exposure to carbon tetrachloride in laboratory animals, including rats, mice, and hamsters, resulted in liver tumors following a variety of routes of administration including inhalation, ingestion, subcutaneous, and intrarectal. One oral dose study on dogs was negative and a trout study gave borderline results. There is no evidence of carcinogenicity to any other organ than the liver, although most studies were shorter than the life-spans of the animals and tumors in other organs cannot be ruled out. In humans, no long-term follow-up study has been reported. Cases of liver tumors in man, following acute poisoning, have been reported (4). While the results cannot be dismissed, their significance is to date unclear. Positive indications of the mutagenicity of carbon tetrachloride have been reported (5). The possible teratogenicity of carbon tetrachloride remains in question.

There is evidence that potentiation may occur between effects of carbon tetrachloride exposure and other stresses. Alcohol consumption, food composition, drug use (especially barbituates), and non-specific environmental stresses are known to potentiate carbon tetrachloride damage in mammals (2,6,7). In contrast, diets rich in certain vitamins or amino acids (notably sulfhydryl-containing compounds) may offer some degree of protection from liver damage resulting from carbon tetrachloride exposure (2).

Several biochemical indices (e.g., serum iron levels, glutamate dehydrogenase activity) have been developed recently that provide indications of past carbon tetrachloride exposure in industrial workers. Such tests forewarn the appearance of the more conventional clinical symptoms of hepatotoxicity (2).

The physical properties of carbon tetrachloride (high vapor pressure and low solubility) should permit some degree of environmental transport, with the majority of movement occurring in the vapor phase. Biochemical degradation occurs to a limited degree in mammalian systems, with major metabolites being chloroform ($CHCl_3$) and carbon dioxide (CO_2). However, no evidence of carbon tetrachloride degradation by microbial action has been found. Carbon tetrachloride shows no oxygen consumption in the standard BOD test (8).

Carbon tetrachloride has been found in a variety of environmental samples at the µg/kg range or lower (see Table III). Sediment samples have not shown any tendency to concentrate carbon tetrachloride to any appreciable degree above the level found in the surrounding water. Bioaccumulation in marine life does not appear to be a problem (bioconcentration factor of 20 in rainbow trout). Observed carbon tetrachloride concentrations vary from 1 µg/kg in fish flesh, to a maximum of 50 µg/kg in seabird eggs and seal blubber. Analyses of a variety of foodstuffs indicate the presence of carbon tetrachloride at levels comparable to those found elsewhere in the environment (see Table IV). It should be noted that cereal grains which have been recently fumi-

TABLE III

TYPICAL CONCENTRATIONS OF CARBON TETRACHLORIDE IN THE ENVIRONMENT

	RANGE (µg/kg wet)
Rainwater	0.01 - 1
Surface water	0.01 - 1
Potable water	0.01 - 1
Seawater	0.1 - 1
Marine sediments	0.1 - 1
Marine invertebrates	1 - 10
Fish	1 - 10
Waterbirds	1 - 100
Marine mammals	1 - 10
Fatty foods	1 - 10
Non-fatty foods	1
Human organs	1
Human body fat	1 - 10

Source: McConnell, G., D. M. Ferguson, and C. R. Pearson. "Chlorinated Hydrocarbons and the Environment." Endeavour, January 1975, p. 13-18.

TABLE IV

OBSERVED CARBON TETRACHLORIDE CONCENTRATIONS IN FOODSTUFFS

	RANGE (ug/kg wet)
Dairy produce	0.2 - 14
Meat	7 - 9
Oils & Fats	0.7 - 18
Beverages	0.2 - 6
Fruit & vegetables	3 - 20

Source: McConnell, G., D. M. Ferguson, and C. R. Pearson. "Chlorinated Hydrocarbons and the Environment." Endeavour, January 1975, p. 13-18.

gated with carbon tetrachloride can contain residues as high as 60 mg/kg, while dairy cows under treatment with a carbon tetrachloride anthelmintic preparation can produce milk containing carbon tetrachloride in concentrations of up to 3 mg/kg (9). In both these instances, dietary intake of carbon tetrachloride can be greatly diminished if adequate time passes (in storage, handling, and processing) between treatment and ingestion. Observed levels of carbon tetrachloride in human tissues have not indicated any inordinate accumulation. As with other chlorinated hydrocarbons, carbon tetrachloride tends to be lipid-soluble, but available evidence indicates no bioaccumulation of carbon tetrachloride in fatty tissues beyond a factor of about 20 over levels found in kidney, liver, brain, and other tissues (1). A 96-hour LC_{50}* of approximately 50 mg/l has been reported in fish (8).

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*Lethal Concentration-50. Concentration lethal to 50 percent of sample population, after 96 hours of exposure.

C. AMBIENT CONCENTRATIONS, POPULATION AT RISK AND MEASUREMENT TECHNOLOGY

Carbon tetrachloride has been monitored extensively in plant atmospheres, and an industrial standard of 65 mg/m^3 8-hour-average daily exposure has been adopted by the Occupational Safety and Health Administration. The chemical is not routinely monitored in ambient air, and only sparse data are available on atmospheric concentrations in population centers. One study in the Los Angeles Basin reveals a concentration range of 1 to 2 $\mu g/m^3$ over 54 ground-level sampling stations in the area, with an excursion to 10 $\mu g/m^3$ near Carson (10). This latter station was possibly located near a source of the material.

Atmospheric concentrations of carbon tetrachloride downwind of production facilities may be estimated from hypothetical plant parameters, when analytical measurements are lacking. The total atmospheric release of the chemical from the 11 production facilities in the United States is estimated to be 15 million pounds per year (5). Hypothetical plant conditions could be used as inputs to a Gaussian plume equation* from Turner's Workbook of Atmospheric Disperson Estimates (11). The basic diffusion equation should be modified, however, due to the effect of the plant itself on the flow of air. Mechanical

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*Ground-level downwind concentrations resulting from a point source are predicted by the following equation:

$$\chi(x, 0, 0; H) = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-1/2 \left(\frac{H}{\sigma_z}\right)^2\right]$$

turbulence in the wake of a building tends to produce aerodynamic downwash, resulting in the fairly rapid diffusion of a gaseous emission down to the ground. This region of disturbed flow extends downwind a distance equal to several times the height of the building. While this situation does not result in a Gaussian-distributed plume, it is proposed that a modification of the usual formula still can be employed. This is because the turbulent mixing in the wake of the building is assumed to be distributed uniformly in the vertical direction, analogous to the situation where a plume is trapped below an inversion layer. A limited vertical mixing height can be modeled using the equation:

$$\chi(x, 0, z; H) = \frac{Q}{\pi \sigma_y u \ (.8L)}$$

where: Q = uniform emission rate (grams/sec)
u = mean wind speed affecting the plume (meters/sec)
H = effective stack height; that is, sum of stack height plus plume rise (meters)
σ_y = horizontal dispersion coefficient evaluated in terms of downwind distance to the point for which the concentration is being computed (meters)
σ_z = vertical dispersion coefficient evaluated in terms of downwind distance to the point for which the concentration is being computed (meters)
L = the vertical limit of the mixing depth

In the case of an isolated rectangular building, it is assumed that L equals 1.5 times the building height.

In addition, there is a horizontal wind turbulence which is assumed to result in an initial horizontal plume spread equal to the width of the building normal to the wind direction. This is analogous

to an area source emission where the area source is the building top. This can be modeled using a further modification of the basic Gaussian diffusion equation. A virtual point source is assumed upwind from the building at a distance where the plume spread (for the given stability conditions) would equal the crosswind width of the building. The modified diffusion equation is therefore:

$$\chi(x, 0, z; H) = \frac{Q}{\pi\sigma_y' u (1.2h)}$$

where H is the building height and σ_y' is based on the downwind distance to the receptor point plus the upwind distance to the virtual point source.

Based on the production losses of individual carbon tetrachloride plants and the assumption that these plants operate 360 days per year and 24 hours per day (assuming 5 days/year downtime), it has been computed that a typical plant would have a carbon tetrachloride emission rate of 20 grams per second. Using the modified diffusion equation, the ambient carbon tetrachloride concentration 500 meters downwind from the release point was calculated to be approximately 1.4 mg/m^3.* The downwind distance of 500 meters from the source was chosen to represent a point within the perimeter of a plant, and ambient concentrations in surrounding neighborhoods could be expected to be

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*Additional assumptions: (1) carbon tetrachloride is nonreactive; (2) building height is 50 feet (15.24 meters), and its width equals 100 feet (30.48 meters); (3) stability class is neutral; (4) wind speed is 6 meters/sec.

significantly lower. The predicted value exceeds background levels measured in the Los Angeles basin by about one thousandfold.

The global atmospheric concentration of carbon tetrachloride is reported to be 0.5 to 1.0 $\mu g/m^3$ at 5 to 10 km altitude (12). The predicted ground-level concentration 500 meters downwind of a plant may exceed this background level by a factor of 1500. There exists no ambient standard for carbon tetrachloride at present, but it is an interesting observation that a resident 500 meters downwind of a plant would receive, in a 75-year lifetime, an exposure equivalent to that of an industrial worker in 7 years of work at the maximum legal occupational level.

The global atmospheric carbon tetrachloride concentration appears to be surprisingly constant (12). The hemispheric concentrations are quite similar, even through the majority of production and use of carbon tetrachloride occurs in the Northern Hemisphere. In addition, carbon tetrachloride does not follow the atmospheric patterns of the other halogenated hydrocarbons (of anthropogenic origin) which tend to occur in clearly defined global isopleths surrounding industrial regions of the world. Finally, the total atmospheric amount of carbon tetrachloride appears to be in excess of those industrial releases of the chemical, even if one assumes no loss through degradation. For these reasons, a natural source of carbon tetrachloride has been suggested, possibly a reaction in the troposphere of methane with chlorine in a complex sequence of reactions. Preliminary laboratory studies

have shown that the reaction in air of methane (CH_4) and chlorine (Cl_2) results in the production of small but significant quantities of carbon tetrachloride (13).

In addition, it is postulated that the chemical may be synthesized by certain forms of vegetation. The entire industrial production of carbon tetrachloride during the twentieth century can account for only two to five percent of the worldwide background concentration (12).

Chemical analysis of carbon tetrachloride at trace levels is well established. Early techniques depended on pyrolytic decomposition of the airborne sample, followed by conventional analysis for liberated chloride. Modern gas chromatographic techniques using an electron capture detector are capable of quantitative analysis for atmospheric carbon tetrachloride at the parts-per-trillion level. Colorimetric and polarographic procedures have also been reported which are suitable for the analysis of environmental and physiological samples of the chemical.

D. SOURCES

Domestic production of carbon tetrachloride was slightly in excess of one billion pounds in 1974, having shown an average growth rate of 6.8 percent throughout the previous decade (14). Demand is estimated to remain at the billion-pound-per-annum level for the 1974-75 period and future growth is uncertain. The carbon tetrachloride market is closely tied to sales of aerosol products, since 95 percent of demand is for the synthesis of fluorocarbon gases and the bulk of these materials is used for aerosol can propellants. The leveling of carbon tetrachloride demand reflects a declining trend in aerosol sales, following a decade of strong growth. Should the use of fluorocarbon propellant be banned in the future, carbon tetrachloride demand could be expected to drop to about 45 percent of its current level.

Carbon tetrachloride production capacity is estimated to exceed current demand by about 50 percent, although plant facilities are generally adaptable to the synthesis of other chlorinated solvents. Certain facilities, known as "swing" plants, are designed to produce carbon tetrachloride and perchloroethylene in variable ratios. The operator may elect to vary the product mix by as much as 50 percent. There are 11 carbon tetrachloride production facilities in the United States, with a total capacity of 1.5 billion pounds per year, located as shown in Figure 1. Detailed supporting data are shown in Table V. Estimates of plant capacity may be misleading, since the proportion of "swing" plants is unknown. Foreign trade in carbon

FIGURE 1
CARBON TETRACHLORIDE PRODUCTION CAPACITY

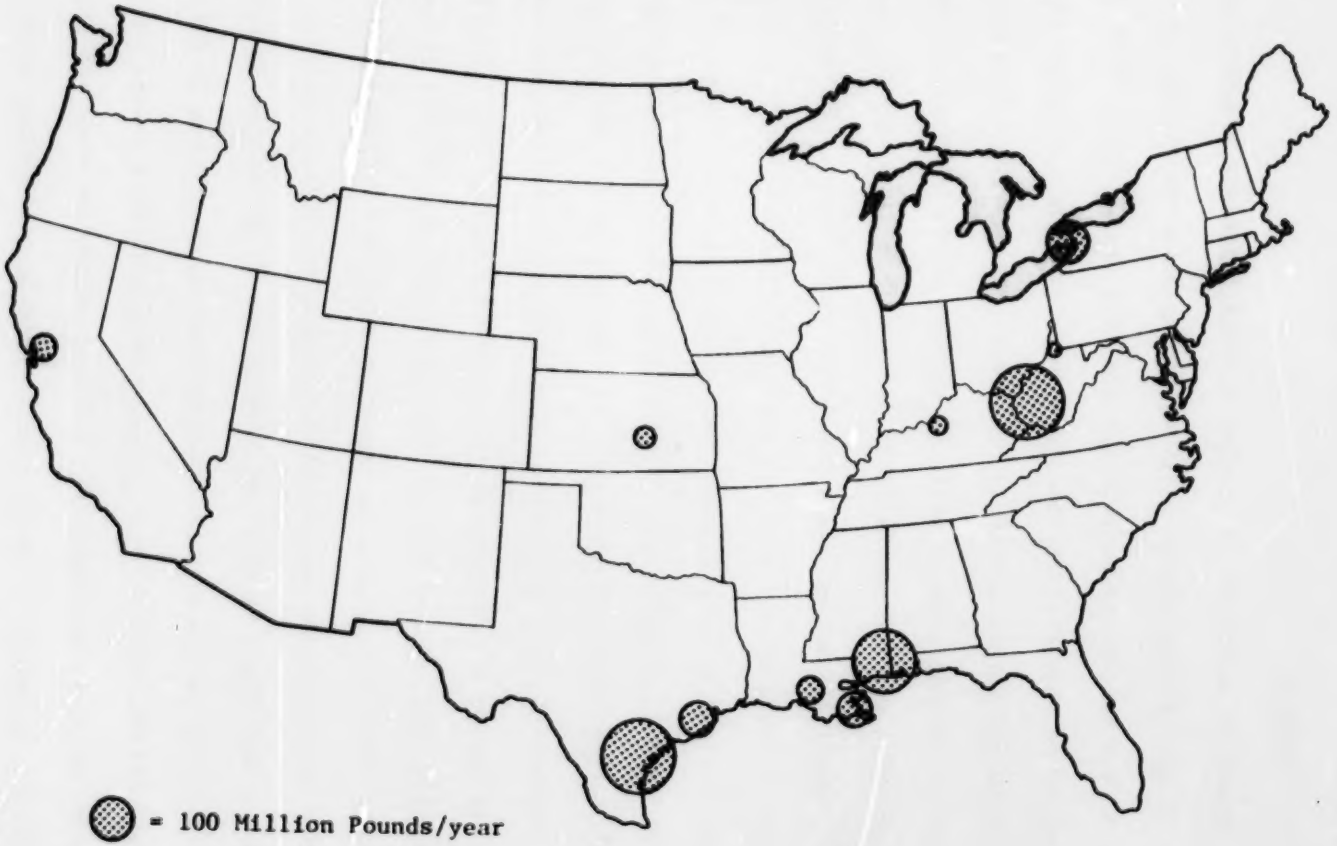


TABLE V

CARBON TETRACHLORIDE PRODUCTION DATA

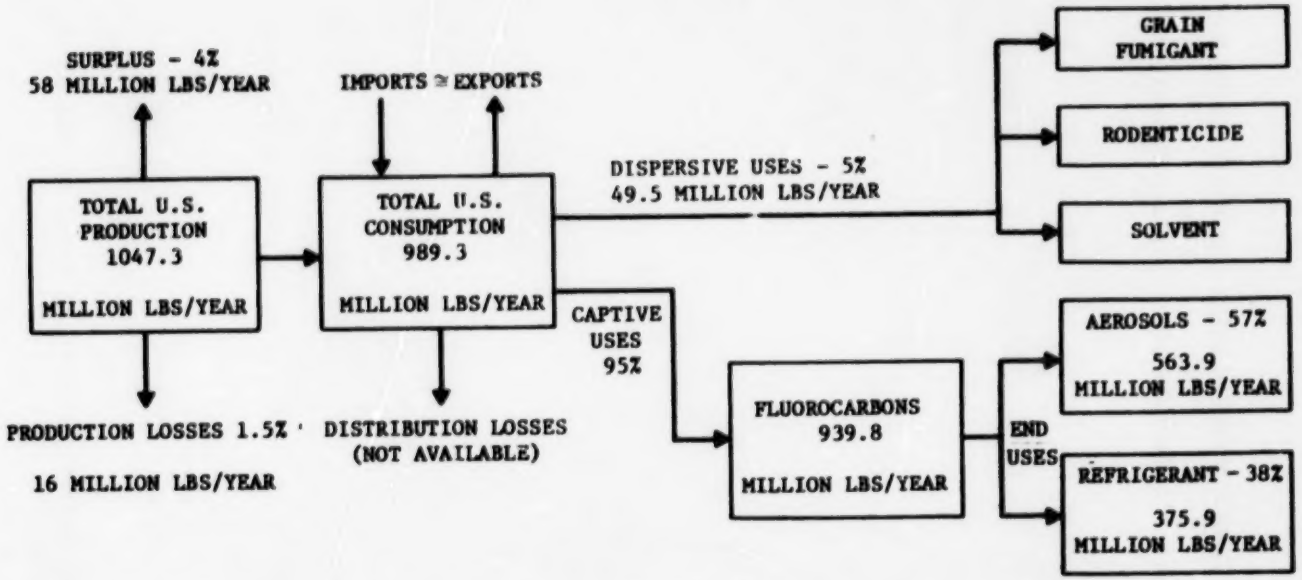
PRODUCER	LOCATION	CAPACITY Million Lbs./yr.
Allied Chemical	Moundsville, WV	8
	Freeport, TX	130
	Pittsburg, CA	45
	Plaquemine, LA	100
DuPont	Corpus Christi, TX	500
FMC Corporation	S. Charleston, WV	300
Stauffer Chemical	LeMoyne, AL	200
	Louisville, KY	70
	Niagara Falls, NY	150
Vulcan Chemicals	Geismar, LA	35
	Wichita, KS	40
	Total Capacity	1,578
	Total Production (1973)	1,047

Source: Stanford Research Institute, Directory of Chemical Producers. Menlo Park, 1975.

tetrachloride appears to be a minor factor in the domestic supply of the material.

Dispersive uses account for 5 percent of carbon tetrachloride production, or about 50 million pounds per year. The chemical is used as a grain fumigant, cleaning agent, rodenticide, anthelmintic, and specialty solvent. Such applications provide direct entry of carbon tetrachloride to the atmosphere. Production losses are estimated to release an additional 15 million pounds per year of the chemical to the environment. Commercial demand for carbon tetrachloride is outlined in Figure 2 and summarized in Table VI.

FIGURE 2
CARBON TETRACHLORIDE–COMMERCIAL PATHWAYS
(1973 DATA)



Source: National Science Foundation Panel on Manufactured Organic Chemicals, SRI Data, 1975.

TABLE VI

CARBON TETRACHLORIDE COMMERCIAL PATHWAYS

(U.S. Production 1.047 Billion Pounds, 1973)

	Percent	Amount (Million Lbs.)
INDUSTRIAL USES		
Freon 11	56.1	587.8
Freon 12	37.4	391.8
DISPERSIVE USES		
Grain Fumigant, Rodenticide, Anthelmintic, Cleaning Agent, Solvent	4.9	51.6
LOSSES		
Production Losses	1.5	15.7
Distribution Losses		(not available)

Source: National Science Foundation Panel on Manufactured Organic Chemicals, SRI Data, 1975.

E. CONTROL STRATEGY

Global studies of atmospheric carbon tetrachloride indicate background levels far in excess of those accountable to industrial sources. The industrial contribution to the atmosphere can account for only two to five percent of the worldwide background level, according to studies of Lovelock and Maggs (13).

The occupational hazard of carbon tetrachloride is well established, and industrial atmospheres are rigidly controlled with regard to solvent vapors. Local populations subjected to industrial losses or other significant emissions of carbon tetrachloride should be protected by control equipment at points of plant emissions. Sources can be controlled with gas scrubbers, adsorption filters, and condensors.

Dispersive applications of carbon tetrachloride probably account for the major occupational and population risks. The use of the material as an insect and rodent fumigant can be envisioned as an application which is inherently difficult to control. It is likely that carbon tetrachloride used in non-industrial applications is subject to no rigid standards for occupational safety or public exposure.

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